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ENVIRONMENTAL INFLUENCES ON OSPREY FORAGING IN NORTHEASTERN NOVA SCOTIA

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ABSTRACT.—We investigated how environmental conditions influenced Osprey foraging behavior in northeastern Nova Scotia. The number of foraging Ospreys and the dives they made peaked at dawn and dusk. Tidal direction had no effect, but the number of foragers and dive successes were highest at mid-tide. The number of foraging Ospreys decreased with diminishing water clarity, yet dive success appeared to increase when the water was murky. Only the number of foragers was affected by cloud cover.

Las condiciones del ambiente y algunas de sus influencias en los hábitos de pesca y alimentación de las Aguilas Pescadoras en el Nordeste de Nueva Escocia

EXTRACTO.—Hemos unvestigado cómo las condiciones del ambiente han influenciado los hábitos de pesca y alimentación del Aguila Pescadora (*Pandion haliaetus*) en el nordeste de Nueva Escocia. El número de Aguilas Pescadoras hambrientas y los buceos que hicieron, aumentaba a su máximo al amanecer y al atardecer. La dirección de la marea no tuvo algún efecto, pero las cantidades de águilas y el éxito en la pesca obtuvieron su máximo a media marea. El número de Aguilas Pescadoras que buscaban alimento decreció con la disminución de la claridad del agua, sin embargo el éxito de los buceos aumentó. Solo el número de águilas en su afán de pesca se vio afectado con tiempo nublado.

[Traducción de Eudoxio Paredes-Ruiz]

Many birds alter their foraging behavior in response to changing environmental conditions (e.g., Dunn 1973, Grubb 1975, Finlay 1976). Factors affecting the foraging behavior of Ospreys (*Pandion haliaetus*) include chronology of the breeding season (Ueoka and Koplin 1973), time of day (Stinson 1978, Boshoff and Palmer 1983), tide (Ueoka and Koplin 1973), wind speed (Machmer and Ydenberg 1990), sunlight (Grubb 1977), water surface condition (Grubb 1977, Machmer and Ydenberg 1990), and the ecology of prey species (Swenson 1979). However, in our northern Nova Scotia study area, Prévost (1977) found that dive success varied only between locations within tidal periods. He did not detect any relationships between search time or dive success with respect to environmental conditions.

The first response that an animal makes to varying conditions is the decision to forage. Curiously, this is often overlooked in studies examining weather-dependent foraging, and studies of the Osprey are no exception. We examined this response, as well as dive frequency, and the percentage of dives which were successful. Our objective was to determine if environmental conditions influenced Osprey foraging behavior in northeastern Nova Scotia.

STUDY AREA AND METHODS

Observations of foraging were made at Antigonish Harbour (45°38′N 62°54′W), Nova Scotia, Canada. This shallow estuary drains a 750 km^2 watershed, and empties into the Northumberland Strait in the Gulf of St. Lawrence The surrounding highlands are covered with deciduous and mixed forests while valley slopes and poorly drained areas are dominated by coniferous forest. Ospreys nest colonially on utility poles along powerline corridors, as well as solitarily on dead or living trees. Males of 29 breeding pairs that nested within 6 km of the estuary regularly foraged at the study site. Others from as far away as 13 km also used the Antigonish Harbour estuary (Jamieson et al. 1982). At our study area, 90% of the diet of coastally nesting Ospreys consists of Winter Flounder (*Pseudopleuronectes americanus*), a cryptic species of flatfish (Prévost 1977, Flemming unpub.).

Observations of foraging (186 hr) were made from either an elevated hide or from a boat. Observation bouts of 3 hr were made during the period 0501–2000 H, 1 May–27 August 1985 and 8 June–8 July 1986. One or two of the five possible bouts were randomly chosen for a given day. At 10 min intervals, we counted (N = 1116 counts) the number of ospreys foraging over a specified census

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Table 1. Effects of environmental conditions on Osprey foraging behavior in northeastern Nova Scotia. Reported values are $\bar{X} \pm$ SD (N).

ENVIRONMENTAL CONDITION		NO. FORAGING PER COUNT	NO. DIVES PER HOUR	PERCENT DIVE SUCCESS
Time of day	0501–0800	0.79 ± 1.40 (198)	1.64 ± 2.16 (33)	50.0 (54)
	0801–1100	0.66 ± 0.99 (240)	1.80 ± 1.25 (40)	74.4 (43)
	1101–1400	0.36 ± 0.72 (162)	0.52 ± 0.94 (27)	57.1 (14)
	1401–1700	0.60 ± 1.06 (240)	1.38 ± 1.75 (40)	63.6 (55)
	1701–2000	1.21 ± 1.70 (276)	2.13 ± 2.58 (46)	63.3 (98)
Direction of tide	Flood	0.70 ± 0.81 (510)	1.34 ± 1.65 (85)	59.6 (114)
	Ebb	0.75 ± 0.91 (606)	1.49 ± 2.11 (101)	64.0 (150)
Tidal amplitude	Low	0.74 ± 1.10 (348)	1.17 ± 1.56 (58)	55.9 (68)
	Mid	0.86 ± 1.41 (444)	1.76 ± 2.17 (74)	70.0 (130)
	High	0.65 ± 1.30 (324)	1.22 ± 1.99 (54)	53.0 (66)
Water clarity	Clear	0.82 ± 1.36 (564)	1.63 ± 2.11 (94)	59.5 (153)
	Hazy	0.83 ± 1.39 (306)	1.25 ± 1.85 (51)	57.8 (64)
	Murky	0.54 ± 0.94 (246)	1.15 ± 1.64 (41)	76.6 (47)
Cloud cover	Clear	0.91 ± 1.45 (222)	1.27 ± 1.97 (37)	59.6 (47)
	Overcast	0.75 ± 1.27 (840)	1.51 ± 1.97 (140)	62.7 (212)
	Raining	0.32 ± 0.70 (54)	0.56 ± 1.33 (9)	60.0 (5)

area (2.5 km^2) at Antigonish Harbour, and evaluated for each dive (prey capture attempt, N = 264 dives), whether or not the Osprey was successful in capturing prey.

We measured four potential environmental influences on Osprey foraging behavior. The diurnal period was divided into 5 3-hr periods (0501–2000 H); tidal amplitude was divided into low, mid, and high (using tide tables), and tidal direction was divided into flood and ebb categories; water clarity was categorized as clear (substrate clearly visible), hazy (objects <10 cm diameter not visible), or murky (objects <20 cm not visible) at a depth of 1 m; and cloud cover was categorized as clear (<10% cloud cover), overcast, or raining.

As the counts of foraging Ospreys were not normally distributed, Kruskal-Wallis tests were used to determine if the number of foragers varied. Dive number and percent success data were normally distributed, so parametric statistics were employed. Analysis of variance was used to test if the number of dives varied, and the Chi-square test was used to determine if dive success was affected. Chi-square tests were performed comparing the proportions of dives which were successful among categories (binomial data, Zar 1984).

RESULTS

The effects of environmental conditions on Osprey foraging in northeastern Nova Scotia are reported in Table 1. The time of day had an impact on Osprey foraging effort (Kruskal-Wallis $F = 10.18$, $P = 0.01$). There were more Ospreys foraging at dawn (0.79 foragers) and dusk (1.21) than at mid-day (0.36). The number of dives/hour followed the same pattern (ANOVA $F = 3.58$, $P = 0.01$). However, time of day did not affect the percentage of dives which were successful ($\chi^2 = 6.40$, $P = 0.18$). Dive success ranged from 50.0–74.4% throughout the day.

Neither the number of foraging Ospreys (Kruskal-Wallis $F = 1.40$, $P = 0.50$), dives/hour (ANOVA $F = 2.39$, $P = 0.21$), nor percent dive success ($\chi^2 = 0.40$, $P = 0.55$) were affected by the direction of the tide. However, the number of foraging Ospreys significantly varied with tidal amplitude (Kruskal-Wallis $F = 3.83$, $P = 0.02$). More Ospreys foraged at the mid-tide (0.86 foragers) than when the tide was low (0.74) or high (0.65). While the number of dives/hour was unaffected (ANOVA $F = 1.87$, $P = 0.16$), it was apparent that mid-tide yielded a greater percentage of dives which were successful (70.0 percent), than either low (55.9) or high tide (53.0) ($\chi^2 = 7.77$, $P = 0.03$).

Fewer Ospreys were foraging when the water was murky (0.54 foragers), than when it was clear (0.82) or hazy (0.83) (Kruskal-Wallis $F = 3.06$, $P = 0.05$). The number of dives/hour was unaffected (ANOVA $F = 1.12$, $P = 0.33$), but there was a weak influence of water clarity on dive success ($\chi^2 = 5.14$, $P = 0.08$). Dive success appeared to increase when the water was murky.

Cloud cover affected the number of foraging Ospreys (Kruskal-Wallis $F = 4.63$, $P = 0.01$), such that fewer birds foraged when it was raining (0.32 foragers), than when it was overcast (0.75) or clear (0.91). Cloud cover did not affect either the number of dives/hour (ANOVA $F = 0.97$, $P = 0.41$), or the percentage of dives which were successful ($\chi^2 = 0.17$, $P = 0.60$).

DISCUSSION

Peaks in Osprey foraging activity have been previously noted. Stinson (1978) found that more fish were brought to the nest early in the day, and Ueoka (1974) found that Ospreys concentrated their foraging effort in the hours immediately after morning fog had dissipated. Similar to our study, Boshoff and Palmer (1983) noted a dawn and dusk pattern in Osprey hunting periodicity. It appears that foraging peaks may be most pronounced at dawn and dusk to compensate for the nocturnal non-feeding period. However, this is unlikely to be the sole explanation for foraging peaks, as Waterston (1961) and Hagan and Walters (1990) noted three and four daily peaks, respectively. Hagan and Walters (1990) reported that the time between foraging peaks corresponded to the length of time required by Ospreys to fly to the foraging area, capture prey, and return to the nest. Hence, the long foraging distance (ca. 14 km) they reported appeared to dictate multiple foraging peaks. Ospreys that nest close to foraging areas could make foraging trips whenever necessary. This would result in a greater degree of randomness in the times at which the foraging area is used. In our study area, most Ospreys nested within 3 km of the foraging area. A few nested as far away as 13 km, but still foraged at Antigonish Harbour (Jamieson et al. 1982). These more distantly nesting Ospreys may have contributed to our observation of two foraging peaks.

We found that the number of foragers and percent dive success peaked at mid-tide, suggesting that Ospreys preferentially foraged during the tidal state that resulted in the highest probability of success. Prévost (1977), who also examined Osprey foraging behavior at Antigonish Harbour, found that dive success varied among locations within tidal periods. He reported that his finding was due to differences in water depth. Hence, lower foraging activity and dive success at high tide would be expected because of the high water depth. Deeper water would inhibit capture of Winter Flounder, which is a bottom feeder. Similarly, lower activity and success would be expected for low tide because Winter Flounders would be forced to the deeper channels, vacating the mudflats which are exposed at low tide. Tyler (1971) found that Winter Flounder also move extensively during the mid-tide. Presumably, Winter Flounders would be easier to detect at mid-tide. Our results appear to be consistent with this behavior.

Ueoka and Koplin (1973) found that successful fishing efforts were highest at ebb (outgoing) tide. Stinson (1978) found the same pattern in one year of his study, but the opposite pattern in the second year. At Antigonish Harbour, we found no pattern associated with tidal direction, only tidal amplitude. Our findings appear to be related to prey behavior, and it is possible that the behavior of prey also explains the different foraging responses to tide among and within other studies. Swenson (1979) found that Osprey dive success varies with prey species foraging behavior.

Fewer Ospreys foraged at Antigonish Harbour when the water was murky. Dive success was similar for clear and hazy conditions, but showed a statistical trend to increase for the murky condition. Given that relatively few birds forage during murky conditions, presumably due to the poor visibility, perhaps the fish taken were the ones near the water's surface, and thus easier to catch. Further examination is required to test this possibility. To date, no other study has examined the effect of water clarity on Osprey foraging behavior, although intuitively it would seem to be an important influence. Our data support this notion.

While the number of foragers decreased as cloud cover increased, like Prévost (1977) and Machmer and Ydenberg (1990), we did not find any relationship with foraging success. However, Grubb (1977) found that when the sun was occluded, hovers, dives, and successful dives/min all decreased significantly. It may be that Prévost's (1977), Machmer and Ydenberg's (1990), and our measures of cloud cover were not fine enough to measure the more immediate foraging responses reported by Grubb (1977).

Although only four environmental influences on Osprey foraging behavior were examined in this study, all four were shown to have an effect. The results differed from a similar investigation (Prévost 1977) at the same study site that concluded there was very little environmental influence. A major reason for arriving at a different conclusion was that, unlike Prévost (1977), we documented how condi-

tions might influence the number of Ospreys which choose to forage at a given time.

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